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# Development of the long-term mass transport model and verification by Chernobyl accident and Sakurajima volcano

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In those days, environmental problems are taken up as the societal issues. Air pollution is one of them. The air pollution cases have been confirmed all over the world. There are some cases that require the long-term prediction and behavior grasp. For example, the radionuclide pollution in Chernobyl and the volcanic gas exposure in the surrounding area. To predict the air pollution and grasp the condition of the air, many models have been studied. Gaussian plume model is the most used among them. However, most models including the model don't assume the long-term prediction.

In this study, we propose the model suited for the long-term prediction, which have not studied enough, and verify the applicability of our model by fitting with measured data.The long-term model in this study is constructed by the governing equation based on the advection equation, and the approximate analytical solution is derived from the mathematical method. The governing equation is the following equation.

$$dC/dt+\{(v_x)d/dx+(v_y)d/dy\}C+l_{env}C+l_{decay}C=P(x,y,t)$$

where $C$ is the concentration in the air, $t$ is the days since the standard time, and $v$ is each forward advection velocity by wind. $l_{env}$ is a local environmental removal rate, that is, the sum of reaction rate by local environmental kinetics such as chemical reactions of the nuclide with soil, permeation into soil, vegetation uptake, water run off, etc. $l_{decay}$ is the physical decay.

$P(x, y, t)$ is the term expressing the emission of pollutant, and the analytical solution differs according to the definition of $P(x, y, t)$.

In this study, the pollution types were divided into four types. As the emission form, the instantaneous emission and the continuous emission were assumed. As the emission source type, the point source and the plane source were assumed.

Fitting with measured data, $P$ was defined according to the cases and the analytical solution was derived in each cases. Radionuclide diffusion derived from Chernobyl Nuclear Power Plant accident was assumed as the instantaneous emission at the point source. In addition, $SO_2$ diffusion derived from Sakurajima Volcano was assumed as the continuous emission at the point source. And derivation of the model(the analytical solution) was assumed about the both cases.

In case of the instantaneous emission at the point source, $P$ was defined as the following equation.

$P=d(x)d(y)d(t).$

and the model was derived. Here, d(x) is delta function. As the result, the model was derived as

$C(t)=A\ exp(-l_{decay}\ t)t^{-a}.$

$A$ and $a$ are fitting parameters.

In case of the continuous emission at the point source, $P$ was defined as the following equation.

$P=d(x)d(y)\{P1d(t1)+...+Pnd(tn)\}.$

$P$ was defined as the sum of delta functions according to times of explosion in this case. The model became the equation including the Fourier transform. So the calculation cannot complete by calculating parameters, and the calculation result was calculated by Mathematica.

As a result, the fitting of 4 radionuclides from Chernobyl Nuclear Power Plant accident was successful at 21 observation points within 40 km.The fitting of period was from 3000 days to 5000 days. The fitting was also showed that calculated parameters $A$ and $a$ has a positive correlation totally but a feature of a positive correlation varied by each radionuclide.Moreover, the fitting of $SO_2$ from Sakurajima Volcano was also successful with the data of Arimura station which can be most affected by Sakurajima Volcano. The period of fitting was from 2002 to 2008.This result showed that the model can calculate the annual oncentration within $\pm$0.005 error.

The above results about two pollution cases shows that the model we proposed was suitable to the long-term prediction of concentration in the air. It is assumed our model can be used in case of the more complicated case such as the continuous emission at the plane source.

Keywords: long-term mass transport model, Chernobyl, Sakurajima volcano, air pollution, dispersion predicting